

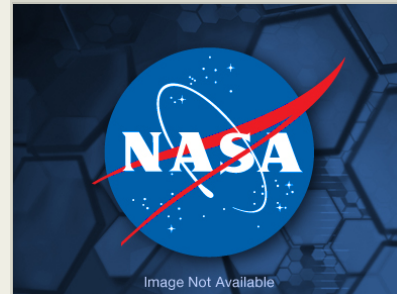
High-speed, Multiband Photometry for Exoplanet Observations

Completed Technology Project (2016 - 2019)



Project Introduction

Detecting and characterizing exoplanets requires exquisite measurement precision. Thanks to NASA's Kepler satellite, there have been over 3,500 potential exoplanets that have been detected using the transit method, and it is expected that there will be hundreds more nearby M-dwarf host star candidates with the launch of NASA's transiting exoplanet survey satellite, TESS. Ground-based follow-up observations to Kepler and TESS detections are crucial for determining planet mass, detecting false positives, and characterizing exoplanetary atmospheres. Unfortunately, ground-based observations are still severely limited by molecular absorption features from Earth's atmosphere, particularly those of water vapor absorption. These features, called telluric lines, are highly variable in time and significantly complicate both ground-based spectroscopy and photometry done in the near-infrared (NIR), where telluric features are most common. Furthermore, incorrect treatment of telluric contamination in addition to instrument systematics can lead to spurious signals in exoplanet atmosphere studies that rely on precise measures of a transiting system's color over time. For ground-based studies to continue pushing their detection limits to be able to determine Earth-sized exoplanet masses and chemical compositions, two complications must be addressed: (1) higher photometric and radial velocity uncertainties due to insufficient correction of telluric variability and (2) instrument systematics compromising the already sparse spectrophotometric data currently used to study exoplanet atmospheres. The proposed project will work to solve both of these problems by developing and testing innovative instruments based on high-speed multiband photometry. In order to safely observe in the NIR, direct measurements of the precipitable water vapor (PWV) in Earth's atmosphere would be sufficient to scale telluric absorption models. These models can then be used to correct photometry or as an input to spectral fitting functions. This research would work to develop an instrument that measures PWV by monitoring the NIR color of a reference star with narrow-band filters, a subset of which will overlap water absorption features. The base for this instrument will be a six-inch telescope with three filters housed in a filter wheel that will transition between each filter every minute. This will cost of tenth the amount of current PWV monitoring systems and be approximately five times more accurate. This research would additionally explore the use of high-speed multiband photometry as a promising alternative to transit spectroscopy for studying exoplanet atmospheres. The analysis would be simpler and the photometry will not suffer from systematics that affect spectra, such as a complicated instrument spread profile and a dynamic blaze function. The PI would develop this instrument and install it on the MINERVA-Red telescope located on Mount Hopkins to perform a survey of the molecular content in hot Jupiter atmospheres. The NIR is ideal for studying M-dwarfs, which are promising host star candidates because they have closer habitable zones and are more common than our Sun. TESS will provide ground-based astronomers with many exoplanet candidates around M-dwarfs that are near enough to perform



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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate
(SMD)

Responsible Program:

Astrophysics

Project Management

Program Manager:

Joe Hill-kittle

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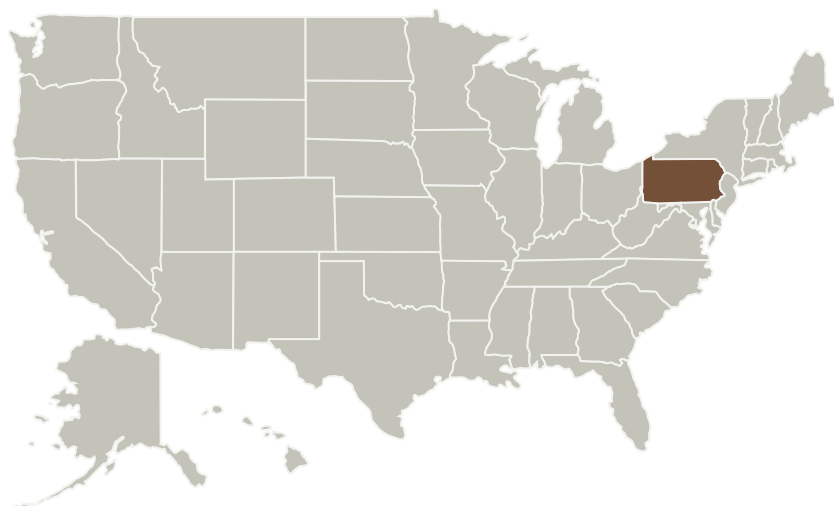
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spectral characterization of their atmospheres. To be prepared for this, the astronomical community must work to determine an accurate way to measure telluric contamination to push the limits of photometric precision and explore alternative instrumental setups that will provide more trustworthy detections of molecular signatures on exoplanets.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Trustees of the University of Pennsylvania	Supporting Organization	Academia	Philadelphia, Pennsylvania

Primary U.S. Work Locations

Pennsylvania

Project Management
(cont.)

Principal Investigator:

Cullen H Blake

Co-Investigators:

Leona Joseph

Ashley D Baker

Technology Areas

Primary:

- TX08 Sensors and Instruments
 - └ TX08.1 Remote Sensing Instruments/Sensors
 - └ TX08.1.5 Lasers

Target Destination

Outside the Solar System